MULTIPLE REGRESSION FORMULAS
FOR USE IN ESTIMATING FISH STANDING CROP
SPORT FISH HARVEST AND ANGLER EFFORT
IN U. S. RESERVOIRS

Revised January 15, 1981

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Since 1963, biologists of the National Reservoir Research Program have compiled and analyzed available pertinent information on the biological, physical, and chemical characteristics of U.S. reservoirs. A primary purpose of the NRRP is to describe and correlate differences in fish production in terms of standing crop as estimated by cove rotenone samples, and by sport and commerical fish yields with such variables as climate, reservoir size, age, uses, shore development, water depth, water level fluctuation, water chemistry, storage ratio, outlet depth, thermocline depth, plankton and benthic fauna crops, and other biological characteristics.

This research has resulted in the development of the following series of multiple regression formulas for use in predicting fish standing crop and angler harvest and effort in U.S. reservoirs. For a review of the relationships between environmental variables and fish standing crop and harvest, as well as a history of the development of multivariate analysis as a method for estimating crop and harvest, see Jenkins (1967, 1974, 1976) and Jenkins and Morais (1971).

Copies of a program incorporating applicable formulas are available from the National Reservoir Research Program in WATFIVE language for the IBM 370/155 computer, or in BASIC for the H-P 9830A calculator.

For further information, write to Dr. Larry Aggus or Mr. David Morais, at the address above, or phone FTS 740-0585 or commericial A/C 501-521-3063.

Multiple Regression Formula Description

Formulas are based on the U.S. Customary system of measures and were derived from data on U.S. reservoirs greater than 500 acres in area at normal pool. Definitions of various types of reservoirs represented in the subsamples and of environmental variables are as follows:

a) All = total sample, representing all types of reservoirs

b) With thermocline = reservoirs in sample which form a stable thermocline (>1°C change in temperature per meter)

c) Chemical type 1 = most of the dissolved solids in the reservoir water are composed of calcium-magnesium, carbonate-bicarbonate (see Rainwater 1962; Hydrologic Invest. Atlas HA-61, Plate 2)

d) Chemical type 2 = most of the dissolved solids are composed of calcium-magnesium, sulfate-chloride

e) Chemical type 3 = most of the dissolved solids are composed of sodium-potassium, carbonate-bicarbonate

f) Chemical type 4 = most of the dissolved solids are composed of sodium-potassium, sulfate-chloride

g) Hydropower storage = reservoirs with hydroelectric power generation and with a storage ratio greater than 0.165 (water exchange less than once in 60 days)

h) Hydropower mainstream = reservoirs with hydroelectric power generation and with a storage ratio less than 0.165 (water exchange greater than once in 60 days)

i) Nonhydropower = reservoirs which do not have a hydroelectric generation function (flood control, irrigation, water supply, recreation reservoirs)

j) "Selected reservoirs" (Formula E) = reservoirs less than 70,000 acres, with total dissolved solids less than 600 ppm, and a growing season greater than 140 days

k) R^2 = coefficient of determination (portion of total variability explained by formula); N = the number of reservoirs in the sample

l) Area = surface area in acres at average annual pool level when data are available; otherwise, use power, conservation, summer or operating pool area

m) Mean depth = in feet, at listed area

n) Outlet depth = midline depth, in feet, of outlet

o) Thermocline depth = in feet at top of thermocline (water temperature change of 1°C/meter or more) on or about 1 August

p) Fluctuation = mean annual vertical fluctuation of the reservoir water surface level in feet

q) Storage ratio = the ratio of the reservoir water volume in acre-feet (at the surface area listed) to the average annual discharge in acre-feet

r) Shore development = the ratio of shoreline length to the circumference of a circle equal in area to that of the reservoir

s) Total dissolved solids = residue on evaporation at 180°C in ppm

t) Growing season = average number of days between the last and first frost.

u) Age of reservoir = in years, following closure of dam

v) Standing crop = estimated crop of fish in pounds per acre as determined by recovery of fishes from coves or open water areas enclosed by blockoff nets following application of rotenone

w) Clupeids = gizzard shad, threadfin shad, blueback herring, Alabama shad, skipjack herring, alewife

x) Sport fish harvest = estimated harvest of fishes by sport fishermen, in pounds per acre per year

y) Commercial fish harvest = estimated harvest by commercial fishermen or rough fish removal crews, primarily by gill and trammel nets and seines, in pounds per acre per year

REGRESSION EQUATIONS FOR STANDING CROP

A. Estimation of standing crop (pounds/acre) - all reservoir types

BA 24

log (standing crop of threadfin shad) = -72.1641 + 0.5012 log (area) + 36.8284 log (growing season) - 0.0664 (growing season)

N = 158 R^2 = 0.19 Prob > F = 0.0001

BA 100

standing crop of buffalofishes = 10.8385 + 13.8428(TDS) - 16.2758 log (storage ratio) - 50.0578 log (mean depth) + 27.6183 log (outlet depth)

N = 112 R^2 = 0.19 Prob > F = 0.0001

BA 118

log (blue catfish standing crop) = -0.201 + 0.9596 log (outlet depth) - 0.0141 (outlet depth)

N = 49 R^2 = 0.14 Prob > F = 0.0378

BA 120

log (flathead catfish standing crop) = -1.3920 + 1.2154 log (TDS) - 0.0015 (TDS) - 0.6343 log (mean depth) + 0.6663 log (fluctuation)

N = 181 R^2 = 0.17 Prob > F = 0.0001

BA 137

(white bass standing crop) = 441.525 + 2.7725(TDS) - 230.4654 log (growing season) + 0.4258 (growing season)

N = 168 R^2 = 0.12 Prob > F = 0.0001

BA 139

striped bass standing crop = -2.896 - 0.3453 log (storage ratio) + 2.626 log (mean depth) - 0.0093 (outlet depth)

N = 35 R^2 = 0.31 Prob > F = 0.008

BA 160

log (sunfish standing crop) = -2.1207 - 0.00024(TDS) - 0.16 log (fluctuation) + 1.6646 log (growing season)

N = 278 R^2 = 0.18 Prob > F = 0.0001

BA 162

log (smallmouth bass standing crop) = -2.9336 + 1.8 log (mean depth) + 0.7376 log (age)

N = 63 R^2 = 0.17 Prob > F = 0.0034

BA 163

spotted bass standing crop = -2.6198 + 2.138 log (mean depth) + 1.368 log (fluctuation)

N = 118 R^2 = 0.26 Prob > F = 0.0001

BA 167

log (white crappie standing crop) = -0.7176 + 1.2655 log(TDS) - 0.0011 (TDS) - 0.9823 log (mean depth) + 0.5596 log (fluctuation)

N = 231 R^2 = 0.25 Prob > F = 0.0001

BA 177

log (walleye standing crop) = 138.931 + 1.0035 log(TDS) + 0.0211 (mean depth) - 75.1972 log (growing season) + 0.1562 (growing season)

N = 79 R^2 = 0.38 Prob > F = 0.0001

BA 178

freshwater drum standing crop = -17.496 + 5.4835 log (area) -0.4595 (mean depth) + 7.6517 log (outlet depth) + 11.9087 log(age)

N = 136 R^2 = 0.17 Prob > F = 0.0001

BA 196

log (sportfish standing crop) = 1.1437 + 0.3892 log(TDS) - 0.00044(TDS)

N = 278 R^2 = 0.25 Prob > F = 0.0001

BA 198

$\log$ (total standing crop minus clupeids) = -1.4563 - 0.454 log (maximum depth) + 0.391 log (outlet depth) + 0.257 log(TDS) + 1.572 log (growing season)

N = 51 $R^2 = 0.44$ Prob > F = 2.1×10^{-5}

B. Estimation of standing crop (pounds per acre) in hydropower mainstream reservoirs

BB 1

total standing crop = - 353.98 + 0.6359(TDS) + 84.912 log (area) - 79.83 log (storage ratio) + 42.05 log (outlet depth)

N = 57 $R^2 = 0.71$ Prob > F = 0.0001

BB 1A

total standing crop = 324 log(TDS) - 384.9

N = 52 $R^2 = 0.74$ Prob > F = 0.0001

(where TDS < 900 ppm)

BB 2

log (total standing crop) = 2.05 + 0.617 log (TDS/mean depth) - 0.093 [log (TDS/mean depth)]2

BB 23

gizzard shad standing crop = 48.5143 + 0.4347(TDS)

N = 52 $R^2 = 0.58$ Prob > F = 0.0001

BB 24

log (threadfin shad standing crop) = 0.8328 - 0.0561 (mean depth) + 2.7338 log (fluctuation) - 0.1036 (fluctuation)

N = 39 $R^2 = 0.51$ Prob > F = 0.0001

BB 26

clupeid standing crop = 151 log(TDS) - 177.2

N = 40 $R^2 = 0.51$ Prob > F = 0.0001

BB 54

log (carp standing crop) = -2.6215 + 2.2282 log(TDS) - 0.0026 (TDS)

N = 50 $R^2 = 0.50$ Prob > F = 0.0001

BB 100

log (standing crop of buffalofishes) = - 5.3443 + 3.6328 log(TDS) - 0.0042(TDS)

N = 27 R^2 = 0.62 Prob > F = 0.0001

BB 137

white bass standing crop = 0.3771 + 0.0054(TDS)

N = 48 R^2 = 0.50 Prob > F = 0.0001

BB 162

log (smallmouth bass standing crop) = -33.0 - 3.115 log (storage ratio) + 9.272 log (mean depth) + 0.08 (growing season)

N = 11 R^2 = 0.75 Prob > F = 0.0166

BB 163

spotted bass standing crop = -33.47 - 1.4608 log (storage ratio) + 0.0954 (mean depth) + 12.9689 log (growing season)

N = 28 R^2 = 0.30 Prob > F = 0.0319

BB 164

log (largemouth bass standing crop) = -4.138 + 2.169 log (growing season) + 0.22 log(TDS) - 0.33 log (mean depth)

N = 55 R^2 = 0.28 Prob > F = 0.0008

BB 167

white crappie standing crop = - 9.2399 + 18.5036 log(TDS) - 0.0233 (TDS) - 3.1631 log (area) + 5.2128 log (storage ratio)

N = 45 R^2 = 0.46 Prob > F = 0.0001

BB 168

black crappie standing crop = 27.3 + 0.0038 (TDS) - 29.2325 log (mean depth) + 0.5764 (mean depth) - 0.0745 (fluctuation)

N = 46 R^2 = 31 Prob > F = 0.0039

BB 178

log (freshwater drum standing crop) = - 0.5223 + 0.3358 log (area) + 0.3446 log (outlet depth) - 0.028 (fluctuation)

N = 29 R^2 = 0.42 Prob > F = 0.0032

BB 198

total standing crop minus clupeids = 167.6 log (TDS) - 196.3

N = 52 R^2 = 0.52 Prob > F = 0.0001

(where TDS < 900 ppm)

C. Estimation of standing crop (pounds per acre) in hydropower storage reservoirs

BC 1

log (total standing crop) = 1.152 + 0.5855 log (TDS)

N = 56 R^2 = 0.50 Prob > F = 0.0001

BC 1A

log (total standing crop) = 2.105 + 0.666 log (TDS/mean depth) - 0.223 [log (TDS/mean depth)]^2

N = 50 R^2 = 0.72 Prob > F = 0.0001

BC 1B

log (total standing crop) = 218 (log TDS) - 239.6

N = 45 R^2 = 0.81 Prob > F = 0.0001

(where TDS < 300)

BC 23

log (gizzard shad standing crop) = 0.0872 + 1.0663 log (TDS) - 0.0012 (TDS)

N = 49 R^2 = 0.31 Prob > F = 0.0002

BC 24

log (threadfin shad standing crop) = - 4.77 + 0.9685 log (storage ratio) + 4.994 log (mean depth) - 0.039 (mean depth)

N = 42 R^2 = 0.22 Prob > F = 0.0225

BC 26

clupeid standing crop = 128.4 log (TDS) - 162.1

N = 42 R^2 = 0.70 Prob > F = 0.0001

BC 54

carp standing crop = 34.756 log (TDS) - 41.5

N = 46 R^2 = 0.33 Prob > F = 0.0001

BC 109

log (redhorse standing crop) = - 6.7152 + 0.5831 log (TDS) + 4.575 log (mean depth) - 0.02 (mean depth)

N = 45 R^2 = 0.23 Prob > F = 0.0125

BC 118

blue catfish standing crop = 4.7513 - 1.0908 log (area) - 6.5005 log (fluctuation) + 0.041 (growing season)

N = 10 R^2 = 0.99 Prob > F = 0.0001

BC 119

channel catfish standing crop = 10.4057 log (TDS) - 13.177

N = 49 R^2 = 0.42 Prob > F = 0.0001

BC 120

flathead catfish standing crop = 0.951 + 7.5736 log (TDS) - 0.01 (TDS) - 10.4236 log (mean depth) + 4.5126 log (fluctuation)

N = 41 R^2 = 0.46 Prob > F = 0.0009

BC 137

log (white bass standing crop) = - 2.803 + 0.9263 log (TDS) + 0.0047 (outlet depth) + 0.5358 log (fluctuation)

N = 33 $R^2 = 0.50$ Prob > F = 0.0001

BC 153

log (bluegill standing crop) = - 7.0207 + 0.328 log (TDS) - 0.0009 (TDS) + 3.3605 log (growing season)

N = 55 $R^2 = 0.30$ Prob > F = 0.0005

BC 160

log (sunfish standing crop) = -0.0065 + 0.4627 log (TDS) - 0.0008 (TDS) - 0.0033 (mean depth) + 0.0043 (growing season)

N = 46 $R^2 = 0.45$ Prob > F = 0.0001

BC 163

log (spotted bass standing crop) = - 6.9806 + 4.8736 log (mean depth) - 0.0381 (mean depth) + 0.5736 log (outlet depth)

N = 33 $R^2 = 0.39$ Prob > F = 0.0024

BC 164

largemouth bass standing crop = 596 - 329.02 log (growing season) + 0.8384 (growing season)

N = 56 $R^2 = 0.30$ Prob > F = 0.0001

BC 177

log (walleye standing crop) = -2.6711 + 1.6011 log (storage ratio) + 0.0149 (mean depth) + 0.9166 log (outlet depth) + 0.0214 (age)

N = 34 $R^2 = 0.46$ Prob > F = 0.0010

BC 178

log (freshwater drum standing crop) = -14.8526 - 1.6896 log (storage ratio) + 9.2818 log (outlet depth) - 0.0426 (outlet depth) + 1.4361 log (age)

N = 29 $R^2 = 0.42$ Prob > F = 0.0032

BC 198

total standing crop minus clupeids = 91 log (TDS) - 78.5

N - 42 R^2 = 0.65 Prob > F = 0.0001

D. <u>Estimation of standing crop (pounds per acre) in nonhydropower reservoirs -- Chemical types 1 and 3</u>

BD 1

total standing crop = -236.7 + 247.8 (log TDS)

N = 43 R^2 = 0.63 Prob > F = 0.0001

BD 2

log (total standing crop) = 1.910 + 0.7356 log (TDS/mean depth) - 0.139 [log (TDS/mean depth)]^2

N = 70 R^2 = 0.58 Prob > F = 0.0001

BD 26

clupeid standing crop = 138.9 log (TDS) - 171.4

N = 40 R^2 = 0.51 Prob > F = 0.0001

BD 54

log (carp standing crop) = - 0.2966 + 0.7641 log (TDS) - 0.0153 (fluctuation)

N = 68 R^2 = 0.30 Prob > F = 0.0001

BD 137

white bass standing crop = - 3.621 + 0.0066 (TDS) + 1.5095 log (area) - 2.5888 log (storage ratio) - 2.3662 log (fluctuation)

N = 51 R^2 = 0.24 Prob > F = 0.0115

BD 160

log (sunfish standing crop) = - 3.3917 - 0.0004 (TDS) - 0.2237 log (area) + 0.1559 log (outlet depth) + 2.4004 log (growing season)

N = 83 R^2 = 0.25 Prob > F = 0.0001

BD 164

log (largemouth bass standing crop) = 0.7989 - 0.1994 log (area) + 0.2663 log (outlet depth) - 0.0018 (outlet depth) + 0.0034 (growing season)

N = 82 R^2 = 0.18 Prob > F = 0.0031

BD 167

$\log$ (white crappie standing crop) = 1.1577 - 0.0244 (mean depth) - 0.3524 log (outlet depth) + 1.1797 log (fluctuation) - 0.0315 (fluctuation)

N = 73 $R^2 = 0.49$ Prob > F = 0.0001

BD 168

black crappie standing crop = 1.2942 + 1.3457 log (area) - 3.5694 log (mean depth) + 1.2185 log (outlet depth) - 1.86 log (fluctuation)

N = 50 $R^2 = 0.37$ Prob > F = 0.0002

BD 177

log (walleye standing crop) = 182.83 + 1.222 log (TDS) + 1.2516 log (mean depth) - 100.123 log (growing season) + 0.2129 (growing season)

N = 21 $R^2 = 0.68$ Prob > F = 0.0007

BD 178

log (drum standing crop) = -10.21 + 0.866 log (TDS) - 0.485 log (storage ratio) + 3.7205 log (growing season) + 0.6715 log (age)

N = 45 $R^2 = 0.41$ Prob > F = 0.0002

BD 198

total standing crop minus clupeids = 84 log (TDS) - 43

N = 43 $R^2 = 0.23$ Prob > F = 0.03

E. Estimation of standing crop (pounds per acre) in nonhydropower reservoirs -- Chemical types 2 and 4

BE 1

total standing crop = 95.3 log (TDS) - 93.1

N = 26 R^2 = 0.77 Prob > F = 0.001

BE 2

log (total standing crop) = 1.758 + 0.7293 log (TDS/mean depth) - 0.209 [log (TDS/mean depth)]^2

N = 72 R^2 = 0.47 Prob > F = 0.0001

BE 1A

log (total standing crop) = 2.089 + 0.1465 log (TDS) + 1.0883 log (mean depth) - 0.0309 (mean depth)

N = 81 R^2 = 0.34 Prob > F = 0.0001

BE 24

log (threadfin shad standing crop) = 9.261 log (growing season) - 19.27

N = 37 R^2 = 40 Prob > F = 0.0002

BE 26

clupeid standing crop = 37.5 log (TDS) - 35.2

N = 23 R^2 = 0.39 Prob > F = 0.03

BE 54

log (carp standing crop) = 0.199 + 0.4518 log (TDS) + 0.4081 log (outlet depth) - 0.013 (fluctuation)

N = 60 R^2 = 0.37 Prob > F = 0.0001

BE 119

log (channel catfish standing crop) = - 0.7543 + 0.7209 log (TDS) - 0.00057 (TDS) + 0.9263 log (outlet depth) - 0.0209 (outlet depth)

N = 71 R^2 = 0.36 Prob > F = 0.0001

BE 137

log (white bass standing crop) = 10.351 + 0.4345 log (area) + 4.3059 log (mean depth) - 0.097 (mean depth) - 6.4351 log (growing season)

N = 35 R^2 = 0.42 Prob > F = 0.0022

BE 153

log (bluegill standing crop) = 2.6958 - 0.2484 log (area) - 0.5864 log (fluctuation)

N = 79 R^2 = 0.19 Prob > F = 0.0003

BE 160

log (sunfish standing crop) = 2.1264 - 0.00024 (TDS) - 0.4762 log (fluctuation)

N = 81 R^2 = 0.19 Prob > F = 0.0002

BE 163

spotted bass standing crop = 313.132 - 159.9482 log (growing season) + 0.2827 (growing season)

N = 21 R^2 = 0.79 Prob > F = 0.0001

BE 164

log (largemouth bass standing crop) = 1.2122 + 0.1517 log (outlet depth) - 0.313 log (fluctuation)

N = 80 R^2 = 0.12 Prob > F = 0.0081

BE 167

log (white crappie standing crop) = 3.42 + 0.3377 log (storage ratio) - 0.0223 (mean depth) - 0.0093 (growing season)

N = 64 R^2 = 0.30 Prob > F = 0.0001

BE 168

log (black crappie standing crop) = 1.0067 - 0.0453 (mean depth) + 0.0135 (outlet depth)

N = 53 R^2 = 0.23 Prob > F = 0.0014

BE 177

walleye standing crop = 660.22 - 0.1038 (fluctuation) - 342.99 log (growing season) + 0.655 (growing season)

N = 15 R^2 = 0.82 Prob > F = 0.0002

BE 178

log (freshwater drum standing crop) = 0.5810 + 0.3261 log (storage ratio) + 1.3258 log (outlet depth) - 0.0349 (outlet depth) + 0.012 (age)

N = 41 R^2 = 0.42 Prob > F = 0.0001

BE 196

log (sportfish standing crop) = 0.9550 + 0.4866 log (TDS) - 0.00049

N = 81 R^2 = 0.42 Prob > F = 0.0001

BE 198A

total standing crop minus clupeids = 56 log (TDS) - 51.1

N = 26 R^2 = 0.55 Prob > F = 0.005

REGRESSION EQUATIONS FOR ESTIMATING

ANGLER EFFORT AND HARVEST

EQUATION

B) Estimation of total annual sport fish harvest - all reservoir types.

log (total sport fish harvest in pounds per acre) = - 0.8104 - 0.2266 log (area) + 0.2090 log (dissolved solids) + 1.1432 log (growing season) - 0.2713 log (age)

N = 103 R^2 = 0.22

D) Estimation of total pounds (not pounds per acre) of sport fish harvested annually.

log (total pounds harvested) = 1.811 + 0.7866 log (area)

N = 208 R^2 = 0.53

E) Estimation of total annual sport fish harvest - selected reservoir types (see definition "j")

log (total sport fish harvest in pounds per acre) = - 0.3892 - 0.1519 log (area) + 0.2027 log (dissolved solids) + 0.9796 log (growing season) - 0.3055 log (age)

N = 46 R^2 = 0.69

G) Estimation of annual black bass harvest - all reservoir types

log (black bass harvest in pounds per acre)= -5.8541 - 0.08691 log (area) + 2.9994 log (growing season) - 0.3336 log (age)

N = 103 R^2 = 0.29

H) Estimation of annual sunfish harvest - all reservoir types

log (sunfish harvest in pounds per acre) = -4.2043 - 0.4669 log (area) + 2.957 log (growing season) - 0.6178 log (age)

N = 103 R^2 = 0.45

I) Estimation of annual sport fish harvest in terms of fish per acre - All reservoir types

log (number of sport fish harvested per acre) = 0.2894 - 0.3437 log (area) + 1.2296 log (growing season) - 0.3761 log (age)

N = 103 R^2 = 0.28

K) Estimation of annual sport fish harvest rate in terms of pounds harvested per angler-hour of effort - all reservoir types.

log (pounds/angler-hour)= -0.8811 + 0.1851 log (area) - 0.0812 log (storage ratio) - 0.0957 log (age) - 0.1207 log (fluctuation)

N = 168 R^2 = 28

M) Estimation of total annual angler effort - all reservoir types.

log (annual angler days per acre) = -3.3925 + 0.9473 log (area) - 0.1729 (log [area] $)^2$ + 0.2387 log (dissolved solids) + 1.1936 log (growing season)

N = 103 R^2 = 0.32

N) Estimation of annual commercial fish harvest - all reservoir types.

log (commercial harvest in pounds per acre) = 6.4819 - 0.492 log (mean depth) - 0.231 log (fluctuation) - 0.204 log (storage ratio) - 2.453 log (growing season) + 0.482 log (age)

N = 45 R^2 = 0.48

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